2005 Revegetation Treatment Results for the Middle Rio Grande Fuels Reduction Study

Project # NMPMC-T-0302-RI

Introduction

The Los Lunas Plant Materials Center (LLPMC) is involved in a study to reduce the amount of fuel load at 12 study sites in the Middle Rio Grande area. The LLPMC is partnering with the following interagency group:

- USFS Rocky Mountain Research Station in Albuquerque
- Bosque del Apache National Wildlife Refuge
- Middle Rio Grande Conservancy District
- City of Albuquerque Open Space
- US Bureau of Land Management
- New Mexico Department of Environment

This study was designed to evaluate the response of groundwater, soil, vegetation, and animal populations to three different types of treatments. These treatments were designed to reduce the amount of fuel load (see Figure 1) or provide restoration by:

1. Mechanically removing or burning (prescribed burns) the dead and downed wood
2. Applying herbicide to control exotic woody species
3. Revegetating three study areas with native plants

Figure 1: Typical appearance a study site before treatment. This is the north edge of the Bosque study site.

The study sites consisted of twelve, 30–50 acre plots that begin at the north-end of Albuquerque and continue south to the Bosque del Apache National Wildlife Refuge. Three of these study sites received revegetation treatments provided by the LLPMC:

- Bosque – Approximately a half mile south of the State Highway 346 Bridge on the west side of the Rio Grande, approximately 10 miles south of Belen.
- Rio Bravo – Approximately one mile south of the Rio Bravo Bridge on the east side of the Rio Grande in south Albuquerque.
- Lemitar – Approximately one mile north of Escondida Bridge on the east side of the Rio Grande, approximately 10 miles north of Socorro.

Figure 2 shows the graphical location of the three study sites.

Figure 2: Map showing the locations of the three study sites (shown in red).

The revegetation study included developing the planting methodologies, installing the plant materials, and performing the follow-up irrigation on plant materials as necessary to maintain their survival during the first two years of establishment.

The goal of the revegetation treatments was to bring the combined shrub and tree density of a site to at least 100 units per acre; the ideal density for maximum diversity and populations for wildlife species in the Middle Rio Grande Bosque (per the late John Taylor, a biologist for the Bosque del Apache National Wildlife Refuge).

In December 2004, the LLPMC conducted a limited pilot study at the request of the Middle Rio Grande Conservancy District (MRGCD) to determine the number of plants to be installed at each site. This study involved subjectively selecting representative sampling points at each of the three study sites. Stakes were driven into the ground and a 117 ½-foot tape was rotated from this stake. All of the stems of shrubs and trees were counted inside the radius of this one acre, circular plot. At the Bosque and Rio Bravo sites, six plots were read. At Lemitar, only four plots were read because this site already had a significantly higher density than the project goal of 100 units per acre (see Figure 3). The pilot study showed the stems-per-acre at each site: 82 at Bosque, 120 at Rio Bravo, and 1,360 at Lemitar. The MRCGD considered these density results and had the LLPMC plant 1,600 shrubs at the Rio Bravo study site, 1,701 shrubs a the Bosque study site, and 400 shrubs at the Lemitar study site. The planting goal was to have more than 100 shrubs per acre at each site.

Figure 3: Typical NM olive understory stand density on both sides of the Lemitar study site road (looking south).

Shrubs and Low-Growing Trees

Methods

Seed from riparian shrub and low-growing tree species was generally collected near the three study sites (within 100 miles). Collected species included: New Mexico olive (*Forestiera pubescens*), indigo bush (*Amorpha fruticosa*), netleaf hackberry (*Celtis reticulata*), willow baccharis (*Baccharis salicina*), golden

currant (*Ribes aureum*), screwbean mesquite (*Prosopis pubescens*), and skunkbush sumac (*Rhus trilobata*). The origin of the seed used for skunkbush sumac was from the PMC cultivar release 'Big Horn' which was originally collected in Montana. The transplants were grown in 30x4-inch PVC pipe tall pots (see Appendix A) or 14-inch deep tree pots. At time of installation, the transplants ranged in age from two–four years, depending upon the time required to produce a mature root ball.

All three sites had adequate stands of cottonwoods and herbaceous understory (see Figure 4). Therefore only native shrubs and low growing trees were planted. Selected species for the three sites was based on the existing species in that area. Each study had its own unique understory shrub composition. For example, screwbean mesquite occurred in the Lemitar area, but it was not found in the Albuquerque area. As a result, screwbean mesquite was planted at Lemitar but not in Albuquerque. On the contrary, golden currant occurred in Albuquerque, but not at Lemitar.

Figure 4: Cottonwoods and herbaceous understory with no shrub component at the Bosque study site; similar vegetation was present at the Rio Bravo study site.

The deep planting technique utilized on the three sites requires little or no follow–up irrigation. The roots of these transplants are planted to the depth of the capillary fringe of the water table (typically 4–7 feet deep). Because the root system is placed into moist soil, it is not necessary to irrigate these plants unless the capillary fringe of the water table drops below the root zone. Most species of plants would not survive this treatment because the root crown is being buried several feet below the surface. Riparian shrub species may tolerate burial by sediments because they have evolved in flood-prone environments.

The plants typically were planted on bare soil in random clusters where the exotic species had been removed. Areas that had dense stands of grass such as alkali muhly (*Muhlenbergia asperifolia*) and forbs such as yerba manza (*Anemopsis californica*) were generally not planted to avoid the competition for water and nutrients from these already dense, established stands (see Figure 5). However there was limited planting in some of these areas with more open stands of herbaceous species. Our intent was to simulate how wood understory species commonly occur in the bosque.

Figure 5: Transplants were not planted in the dense stands of the herbaceous broadleaf understory yerba manza (*Anemopsis californica)* which dominates at this location in the Bosque study site.

At the Rio Bravo site, 800 tall pot transplants were installed from October 27 through November 14, 2003. An additional 800 tall pots were planted at Rio Bravo from October 24 through November 4, 2005. See Table 1.

Table 1: Rio Bravo Study Site Planting

Species	Planting Dates	Container Type	Total Planted
NM olive	10/27/2003 to 11/14/2003	Tall Pot	497
	October 2005	Tall Pot	620
Skunkbush sumac	10/27/2003 to 11/14/2003	Tall Pot	165
	October 2005	Tall Pot	105
Wolfberry	10/27/2003 to 11/14/2003	Tall Pot	97
	October 2005	Tall Pot	0
Golden currant	10/27/2003 to 11/14/2003	Tall Pot	41
	October 2005	Tall Pot	75
Grand Total			1,600

At the Bosque site, 558 tall pots and 388 tree pots were planted in January 2005, and 805 additional tree pots were planted in November 2005. See Table 2.

Table 2: Bosque Study Site Planting

Species	Planting Dates	Container Type	Total Planted
NM olive	01/18/2005 to 01/27/2005	Tall Pot	226
		Tree Pot	213
	11/07/2005 to 11/11/2005	Tree Pot	269
Indigo bush	01/18/2005 to 01/27/2005	Tall Pot	68
		Tree Pot	14
	11/07/2005 to 11/11/2005	Tree Pot	268
Netleaf hackberry	01/18/2005 to 01/27/2005	Tall Pot	152
		Tree Pot	0
	11/07/2005 to 11/11/2005	Tree Pot	0
Willow baccharis	01/18/2005 to 01/27/200	Tall Pot	0
		Tree Pot	111
	11/07/2005 to 11/11/2005	Tree Pot	268
Screwbean mesquite	01/18/2005 to 01/27/2005	Tall Pot	0
		Tree Pot	32
	11/07/2005 to 11/11/2005	Tree Pot	0
Wolfberry	01/18/2005 to 01/27/2005	Tall Pot	0
		Tree Pot	18
	11/07/2005 to 11/11/2005	Tree Pot	0
Golden currant	01/18/2005 to 01/27/2005	Tall Pot	112
		Tree Pot	0
	11/07/2005 to 11/11/2005	Tree Pot	0
Grand Total			1,751

At the Lemitar site, 400 tall pots were installed December 1–4, 2003. See Table 3.

Table 3: Lemitar Study Site Planting

Species	Planting Dates	Container Type	Total Planted
NM olive	12/01/2003 to 12/04/2003	Tall Pot	112
Willow baccharis	12/01/2003 to 12/04/2003	Tall Pot	110
Screwbean mesquite	12/01/2003 to 12/04/2003	Tall Pot	90
Wolfberry	12/01/2003 to 12/04/2003	Tall Pot	88
Grand Total			400

A 65-horsepower farm tractor with an 8-foot auger mounted on the front end was used to dig the holes for the tall pots (see Figure 6). Plants were placed to the depth of the capillary fringe of the water table, and the holes were backfilled by hand with shovels. The plants at all three sites were planted in random clusters and as individuals. Before backfilling, a PVC pipe (40-inches in length and 1-inch in diameter

with perforations on the bottom third of the pipe) was placed in each hole for future irrigation applications. These irrigation pipes rise approximately 10 inches above the ground, making it easier to locate the transplants. Even though the soil was moist at the time of planting, the plants were irrigated after planting primarily to collapse any air-pockets and achieve good root-to-soil contact.

Figure 6: Planting holes being dug by a 65-horsepower tractor with an 8-foot auger mounted to the front end. The plants were installed by hand as deep as 7 feet to reach sub-surface moisture.

By applying irrigation water through the PVC pipes, water flows near and below the root tips to encourage the root system to continue to grow towards the water table (see Figure 7). Another benefit to irrigating through the plastic pipes is that the soil surface remains dry. If the soil surface is irrigated on these highly productive riparian sites, it often promotes weed seed germination, emergence, and growth. These weeds are generally more competitive for light, nutrients, and water than the desired plants, and as a result may reduce the plants' survival or growth rate.

The shrubs, planted in 2003 at the Rio Bravo and Lemitar study sites, were irrigated three times during the dry conditions of 2004, once in June, once in July, and once again in September. Each application consisted of approximately 4–5 gallons of water. Irrigation water was applied with a 300-gallon tank located in the bed of a pickup. Water was pumped from the tank with a 4-horespower, high-pressure (70psi) pump. It typically takes about three days using two irrigation trucks operated by four technicians to irrigate 800 plants.

Other than watering in newly planted plants, the 2005 irrigation at the three study sites only occurred once in August at the Lemitar site because the water table had dropped below the reach of the plants' roots. At the Rio Bravo and Bosque study sites, the water table never dropped below 5 feet, allowing for continuous, natural sub-irrigation of the plants. This high water table was unusual for this area and only occurred because the watershed of the Rio Grande in southern Colorado and northern New Mexico received about twice the amount of normal snow pack (approximately 150 inches by spring). As a result, the high volume of run-off from snow melt kept flows in the Rio Grande high all summer. These high flows provided for lateral seepage in the river bank that resulted in recharging shallow ground water along the river corridor.

Figure 7: Irrigating transplants through the PVC pipes keeps the soil surface dry and allows water to flow near and below the root tips to encourage the root system to grow towards the water table.

Results and Discussion

Survival results for all three study sites were based on the amount of live and dead plants found. Both the dead plants and the live plants were easy to locate because they were flagged by the 10-inch, above ground portion of the irrigation tube.

Rio Bravo – The survival rate at the Rio Bravo study site averaged 92 percent by September 2005 (see Table 4 and Figure 8). In July 2004, a wild fire on the south side of this site may have killed about 100 of the transplants which we were unable to find. The fire destroyed the irrigation tubes so resprouting shrubs could not be positively identified as transplants. In some areas, this site also had become overgrown with root sprouts of tree of heaven, Russian olive and several species of annual weeds. This made it difficult to locate the transplants in this dense underbrush. Of the 800 transplants that were installed in October 2003, only 565 were found. The survival rate of New Mexico olive was at 99 percent, skunkbush sumac at 90 percent, wolfberry at 97 percent, and golden currant at 81 percent. New Mexico olive seemed to be the most vigorous, with some of them doubling in size (up to 8 feet in height) by the Fall of 2005. The wolfberry lacked vigor from growing in the dense shade and their leaves were etiolated and sparse.

Table 4: Rio Bravo Study Site Survival Rates From the October/November 2003 Planting

Species	Total Planted	Total Plants Located	Total Plants Alive as of 10/05	Total Plants Dead as of 10/05	Percent Located	Survival Rate of Located Plants
NM olive	497	397	382	15	80%	99%
Skunkbush sumac	165	110	100	10	66%	90%
Wolfberry	97	37	36	1	38%	97%
Golden currant	41	21	17	4	51%	81%
Grand Total	800	568	535	30		
Average Survival Rate						92%

Figure 8: Typical transplant shrub density and growth in October of the second growing season at the Rio Bravo study site.

Bosque – The survival rate at the Bosque study site for all species of transplants averaged 91 percent (see Table 5 and Figure 9). All of the transplants were found at this site. The site remained open with only native grass generally occupying ground level so the transplants could be located easily. The survival rate of New Mexico olive was at 99 percent, indigo bush was at 100 percent, netleaf hackberry was at 91 percent, willow baccharis was at 100 percent, golden currant was at 100 percent, screwbean mesquite was at 94 percent, and wolfberry was at 67 percent. All of the species of transplants were doing excellent at this site except for the wolfberry. This location has a fairly dense cottonwood canopy which may not allow for adequate sunlight to allow vigorous growth of wolfberry (similar to the Rio Bravo site).

Most of the transplants that died were planted in surface depressions where there was standing water for a period of 60 days or longer. This occurred in May, June, and July of 2005. This standing water was caused by unusually high flows in the river, and as a result, significantly raised the water table at this site. Because of the high water table, low surface depressions became shallow ponds. None of the transplants that were planted in the depressions survived (no matter what the species).

Table 5: Bosque Study Site Survival Rates From the January 2005 Planting

Species	Total Planted	Total Plants Located	Total Plants Alive as of 10/05	Total Plants Dead as of 10/05	Percent Located	Survival Rate of Located Plants
NM olive	439	439	437	2	100%	99%
Indigo bush	82	82	82	0	100%	100%
Netleaf hackberry	152	152	139	13	100%	91%
Screwbean mesquite	32	32	30	2	100%	94%
Wolfberry	18	18	12	6	100%	67%
Golden currant	112	112	106	6	100%	95%
Willow baccharis	111	111	111	0	100%	100%
Grand Total	946	946	917	29		
Average Survival Rate						97%

Figure 9: Typical transplant shrub density and growth in October of the first growing season at the Bosque study site.

Lemitar – The survival rate at the Lemitar study site for all species of transplants averaged 83 percent for all those that were found (see Table 6 and Figure 10). Of the 400 transplants installed, 285 were found. This site already had dense stands of native shrubs before the planting that made it difficult to find some transplants. This site also had continuous grazing by approximately 20-head of cattle that often browsed the transplants. Most transplants had browse damage, but it seemed the cattle preferred willow baccharis, with many of these plants being browsed more than 50 percent. Survival of New Mexico olive was at 95 percent, willow baccharis at 94 percent, wolfberry at 73 percent, and screwbean mesquite at 70 percent. Willow baccharis appeared to display the highest vigor of the four species. Many might have doubled in size if they had not been browsed regularly. A few isolated plants were huge. The screwbean mesquite generally defoliated in mid-summer of 2004; however most plants leafed-out in the spring of 2005 and put on about 12 inches of new growth. Wolfberry also defoliated in mid-summer of 2004, but so did the local, on-site wolfberry. The plants appeared to have acquired a foliar fungal disease that turned the leaves to a gold/black color and defoliated; however most of these plants appeared to be healthy again by the Spring of 2005 and through the Fall of 2005.

Table 6: Lemitar Study Site Survival Rates From the December 2003 Planting

Species	Total Planted	Total Plants Located	Total Plants Alive as of 10/05	Total Plants Dead as of 10/05	Percent Located	Survival Rate of Located Plants
NM olive	112	95	90	5	85%	95%
Willow baccharis	110	83	78	5	75%	94%
Wolfberry	90	51	37	14	53%	73%
Screwbean mesquite	88	56	39	17	64%	70%
Grand Total	400	285	244	41		
Average Survival Rate						83%

Figure 10: Typical transplant shrub density and growth situated between a natural stand of NM olive and wolfberry in October of the second growing season. The transplants are easily identified by their irrigation tubes.

Pole Cuttings

Methods

Dormant, understory pole cuttings of western black willow (*Salix goodingii*), indigobush, willow baccharis, and New Mexico olive were planted primarily close to the Rio Grande (within 100 feet) at the Rio Bravo and Bosque study sites. The origin of the pole cuttings were from locations within 100 miles or less from the study sites. Poles cuttings were grown in production plantations at the LLPMC where they were irrigated and fertilized to maintain a vigorous stock (see Figure 11). The day before planting, three-to-five year-old sapling shrubs (8–15 feet tall) were cut using a chainsaw. Side limbs of these cuttings were removed with hand pruners, but the branch collars on the pole cuttings were left intact. The terminal end and about two side limbs were left on each cutting. After harvest, the cuttings were placed in water baths to maintain hydration.

Four random soil samples were taken at a 12-inch depth at the Rio Bravo and Bosque study sites where poles had been planted. A soil saturation paste was prepared for each sample and measured for electrical

conductivity (EC) using a Hanna HI 991300 field meter. A commercially prepared standard (1.413 dS/m) of potassium chloride was used to develop a standard curve. The meter consistently read a lower value, of about 0.1 dS/m, which was corrected in the individual soil sample EC measurements.

Figure 11: A pole cutting plantation of willow baccharis at the Los Lunas Plant Materials Center. This plantation is in its tenth growing season; the longer stems are approaching 12 feet in height.

At the study sites, the pole cuttings were planted into 8-foot holes that were 10-inches in diameter. The holes were drilled using an auger mounted to the front-end loader of a 65 horsepower farm tractor (see Figure 12). Then the holes were backfilled by hand and compacted to remove air pockets to achieve good soil-to-stem contact. Cuttings were planted only in holes that exposed the water table at a depth of 4 feet or more. Dry holes were backfilled without planting.

Figure 12: Los Lunas Plant Materials Center crew members are planting understory pole cuttings on the east bank of the Rio Grande at the Bosque study site.

Results

At the Rio Bravo study site, 543 pole cuttings were planted; half were planted in March 2004 and the other half planted in March 2005 (see Table 7 and Figure 13).

Table 7: Rio Bravo Study Site Pole Cuttings Survival Rate

Species	Number Planted	Planting Date	Number Planted	Planting Date	Number Alive	Survival Percentage Rate
NM olive	85	March 2004	85	March 2005	19	11%
Indigobush	54	March 2004	54	March 2005	30	28%
Willow baccharis	65	March 2004	65	March 2005	2	1%
Western black willow	68	March 2004	67	March 2005	84	45%
Grand Total	272		271		135	
Average Survival Rate						21%

Figure 13: Established indigobush pole cutting (center) by the end of the second growing season in October 2005.

At the Bosque study site, 1,004 pole cuttings were planted in March of 2005 (see Table 8 and Figure 14).

Table 8: Bosque Study Site Pole Cuttings Survival Rate

Species	Number Planted	Planting Date	Number Alive	Survival Percentage Rate
NM olive	73	March 2005	1	1%
Indigobush	324	March 2005	91	28%
Willow baccharis	213	March 2005	1	0.5%
Western black willow	394	March 2005	69	18%
Grand Total	1004		162	
Average Survival Rate				12%

Figure 14: Established indigobush (foreground, left) and western black willow (center) with several dead pole cuttings in the background (right).

No cuttings were planted at the Lemitar study site because the water table depth was greater than the 8-foot depth of the planting equipment used by the LLPMC.

Rio Bravo – The survival rate of the pole cuttings at the Rio Bravo study site averaged 21 percent. The survival rate of western black willow was at 45 percent, indigo bush at 28 percent, NM olive at 11 percent, and willow baccharis at 1 percent.

Bosque – The survival of pole cuttings at the Bosque study site averaged 12 percent. Survival of indigo bush was at 28 percent, western black willow at 18 percent, New Mexico olive at 1 percent, and willow baccharis at 0.5 percent.

At the Rio Bravo study site, soil EC measurements were 0.2 dS/m, 0.6 dS/m, 0.5 dS/m and 0.7 dS/m. At the Bosque study site soil EC measurements were 1.8 dS/m, 0.6 dS/m, 1.0 dS/m, and 0.5 dS/m. All of these measurements for both study sites are in the acceptable range where salt concentration in the soil should not be detrimental to root formation of the understory pole cutting species planted.

The survival rate of pole cuttings at Rio Bravo and Bosque was lower than anticipated. Both sites had a dense over-story canopy of cottonwoods, limiting the amount of light which reduced the establishment of the pole cuttings. Additionally, the pole cutting production plantations at the LLPMC for all species are

now older than 10 years, and they seem to be less vigorous which may limit field establishment. Even when the production plantations were new, it was unusual to achieve a survival rate of greater than 50 percent for these species.

Summary

The LLPMC continues to develop or refine planting methodologies and plant materials that require little or no follow-up irrigation. Riparian areas are unique in the dry climate of the Southwest because they typically have shallow water tables due to the lateral seepage of water from a source, such as a river. The planting methods developed by the LLPMC usually involve strategies designed to tap into this moisture. Demonstration plantings like this study provide the LLPMC an opportunity to measure the effectiveness of these methods before they are released to cooperators and the general public.

The survival rate of riparian shrub transplants with limited or no follow-up irrigation averaged 90% or greater for the three study sites. These study sites are located in the desert where they receive less than 10 inches of annual precipitation. By digging holes in a riparian zone deep enough to reach the capillary fringe of the water table, we were able to place the transplants' roots into the subsurface moisture. To achieve this depth, the root crowns of the transplants were buried up to 6 feet below the soil surface. This did not seem to have an effect on their survival or vigor.

Because this planting technique of riparian shrub transplants has worked so well at the three study sites, the LLPMC will no longer encourage the planting of unrooted, understory pole cuttings; however, the pole cutting methodology is still an excellent planting technique to establish cottonwoods and willow trees without follow-up irrigation.

Appendix A

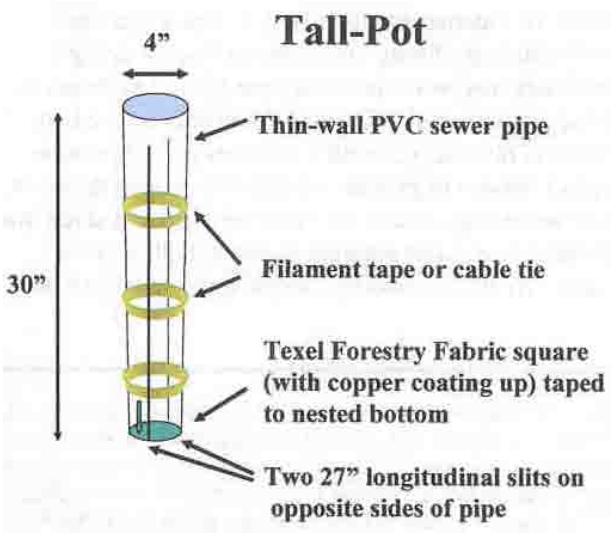
Tall-Pots

Tall-pots are being used by the USDA-NRCS Los Lunas Plant Materials Center for revegetation of disturbed xeric sites which would require appreciable irrigation if conventional woody plant establishment methods were used. Pilot studies investigating tall-pot technology have been conducted on highway medians and along right-of-ways in semi-arid pinon-juniper zones, in disturbed riparian areas with deep (greater than four feet) water tables, and at other critical area planting sites where conventional irrigation is not technically or economically feasible.

Tall-pots allow the development of deep root systems capable of using subsurface soil moisture occurring in two contrasting situations:

1. arid sites with thick soil profiles and deep soil moisture (i.e., not subject to loss by surface evaporation) or
2. riparian areas where soil moisture is present in the capillary fringe above a relatively deep water table (e.g., the fringe extends from the water table to about three to four feet below the soil surface).

The LLPMC has modified traditional tall pot designs to reduce pot costs and improve plant growth in the nursery. Inexpensive thin wall four-inch diameter PVC sewer pipe is split lengthwise to provide a tapered pot for easy root-ball removal and to discourage root spiraling. The bottom of a tall-pot is covered with copper hydroxide coated spun-bonded fabric to control root egress and allow drainage. The LLPMC tall-pots are typically 30” long (or four pots from a 10-foot pipe section).


Tall-Pot
4”
30”
Thin-wall PVC sewer pipe
Filament tape or cable tie
Texel Forestry Fabric square (with copper coating up) taped to nested bottom
Two 27” longitudinal slits on opposite sides of pipe

The LLPMC is investigating methods to enhance transplant survival in the arid Southwest while minimizing the expense of providing sufficient supplemental water to assure establishment. Beyond the benefits of a long root ball to access soil moisture deep in the soil profile, the use of a limited number of subsurface water applications has provided high survival rates of shrubs planted on and sites. In pilot projects on sites disturbed by highway construction near Santa Fe, New Mexico, thousands of native shrubs (including New Mexico olive, skunkbush sumac, and wavyleaf oak) were grown in tall pots and were planted with perforated watering tubes to allow the application of water deep into the soil profile. Several years after planting, the survival rates for well-adapted species during the current drought exceed 95 percent.

A watering tube is placed adjacent to the root ball in an augered hole, which is two to five inches greater in diameter than the four inch mot ball. The goal of watering tubes is to apply sufficient water to produce a store of deep subsurface moisture not subject to surface evaporation. The bottom of the tube reaches the bottom of the planting hole. Perforations along the lower half of the tube allow water to move into the lower soil profile and result in minimal wetting of the soil surface to minimize weed growth and evaporation losses.

The planting hole containing the 30” root ball and watering tube needs to be backfilled with care. Voids in the backfill can be minimized by surface watering to wash soil into the void space, if irrigation water is readily available immediately after planting. Since fall plantings are generally preferred, the application of this surface water will not generally encourage troublesome weed growth except occasionally some winter annual weeds.

Larger diameter watering tubes (three to four inches) can accommodate the application of starch-based polymer hydrogels that provide a slow release of water to the subsoil that replenishes water used by plant transpiration. Smaller diameter one inch water tubes can be used for the application of plain water.

The advantage of using hydrogel is that fewer applications of water are needed to assure establishment but this must be weighed against the cost of the polymer and the greater difficulty in applying this gelatinous material.

In plantings using tall-pots, the number of water applications required depends on the ease and expense of providing water to the watering tubes, the drought tolerance of the species, the existing and expected drought conditions at the site, and the depth to ground water (in riparian situations only). Our experience with plantings during the recent multi-year drought indicates that two applications per year of hydrogel or three applications of water will probably assure high survival rates on xeric sites. On sites receiving some run-off harvest or greater precipitation, one hydrogel or two water applications will probably be needed for two to three years after planting to obtain high survival rates.

We have generally tried to apply water just as growth resumes in the spring and again in early fall to assure adequate soil moisture through the typically dry autumn period.

In some situations, an annual subsurface water application for a few years might be sufficient for acceptable survival percentages or even a single watering at planting might suffice; however, considering the expense of tall-pot plant material and the cost of installing tall-pots, adequate water application to maximize survival potential is usually justified. Successful plant establishment requires the propagation of roots into the capillary fringe for riparian plantings or the proliferation of roots capable of mining stored soil moisture for plantings on and sites.

In riparian areas with shallow ground water providing a capillary fringe at two to three foot depths, water tubes are not necessary. Other situations that may not require watering tubes would be semi-arid sites with appreciable rainfall harvest potential and porous soil allowing sufficient recharge of deep soil moisture. If precipitation levels return to the elevated averages of the recent past, only minimal subsurface water application may be required for plant establishment on many xeric sites.

Tall-pots require fabrication which is relatively expensive due to the labor involved compared with the cost of commercially available containers. The production of tall-pot plants takes considerable time so substantial lead-time is required to propagate appropriate species for each particular revegetation project. If large containerized or bare-root seedlings are available, tall-pot production will require at least one growing season for fast growing species (e.g., such as willows and cottonwoods), two to three growing seasons for many upland and riparian shrubs and trees (e.g., New Mexico olive, skunkbush sumac, shrub oaks), and as much as four years for slow growing desert species (e.g., yuccas, agaves, beargrass).

Although the production and initial maintenance of outplanted tall-pots requires a significant investment of time and money, there are many situations in arid and semi-arid regions of the Southwest where this technology will be more effective than other currently available establishment techniques.

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